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# INNOVATIONS IN PEDAGOGICAL DIDACTICS OF TEACHING PHYSICS TO UNIVERSITY STUDENTS

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## ABSTRACT

The relevance of the study lies in the lack of information about the current processes in understanding and applying innovative practices of teaching physics in the current conditions of systematic transformation of professional education. In the context of the main purpose of teaching and the need to improve the quality of educational services offered, considering interdisciplinary advances in the fields of science, we consider it timely to conduct an additional study of the potential and limitations of didactics of pedagogical science from the position of multifactorial influence of universal informatization, transforming the nature of interactions at various levels. This study aims to identify teachers' views on the opportunities and risks of innovation, as well as to establish the range of pedagogical tools they use to improve students' learning in physics. To this end, a non-experimental quantitative design was used, involving the collection of information through a questionnaire completed by 24 physics teachers in an interview survey, providing additional questions in the context of the research objective. In obtaining the results, the rules of analysis and validity criteria of the data recorded in the protocols were followed, through the procedure of measuring the level of agreement between the interviewer by category and checking the reliability of the analyzed data.The results show the possibilities of effective application of innovations by teachers in the process of teaching physics, the study and systematization of which can further improve the quality of educational services and competitiveness of specialists.



Keywords: didactics of pedagogical sciences, innovative teaching, practice of pedagogical education, professional development of physics teacher, student learning

## INTRODUCTION

The principles governing the teaching of physics are currently based on the concept of teachers' independent and critical understanding of the potential of opportunities offered by the achievements in different fields of knowledge in view of the current trend towards interdisciplinarity of knowledge spheres (Lee et al., 2023; Docktor et al., 2014; Jarosievitz et al., 2021). Based on these principles, teachers analyze the available pedagogical tools, independently assess their capabilities and implement them in pedagogical practice in order to transform the educational space and solve the tasks of professional training of specialists within its boundaries (Shah et al., 2023; Kohlbacher et al., 2016; Motz et al., 2021; Nuere et al., 2020; Cook, 2002; Küçüközer et al., 2007; Harrer et al., 2013; Ole, 2018).

Such training should foster a holistic view of the world that takes into account a set of diverse spaces, the existing real-world situation, and a local and global view of hitherto unsolved problems (Hasan et al., 2021; Kannan et al., 2020; Nantsou et al., 2022; O'Brien et al., 2021; Romadhon et al., 2021; Duckworth et al., 2021; McDermott et al., 2001). Given the importance of teaching physics in a world full of change and uncertainty, it is necessary to ask what type of professional preparation future teachers will need

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to guide school students in the process of developing their social thinking (Christopoulos et al., 2023; Klapproth et al., 2020; Puspisatari et al., 2021; Docktor et al., 2014; Goris, 2016).

In this regard, it is also worth asking whether education specialists are prepared to teach physics from a critical and emancipatory point of view and whether students are sufficiently prepared to perceive the mass of information currently prevailing in all spheres of human activity (Kong et al., 2020). This is the reason for the organization of the present study, designed to identify the views of teachers on the creation of a new didactic model for organizing the process of teaching physics to students, designed to subsequently implement the mastered knowledge and acquired skills within the walls of general educational institutions (Klein et al., 2021; Jelicic et al., 2022; Elby et al., 2007).

The prevalence of traditional teaching models demonstrate their failure in view of outdated mechanisms of translation of knowledge and operational components, which determines the importance of identifying the current situation of implementation of innovative didactic tools in connection with the current - traditional (Paechter et al., 2021). Since the pedagogical actions of teachers in the process of teaching physics to students are based on the practice of teaching in the classroom of an educational institution, ensuring adequate professional training should be the main motivation for improving pedagogical practices (Holzer et al., 2021).

Thus, in order to achieve these goals in the context of higher education, it is necessary to start with a change in methodological approaches that address the problematization of content in relation to past and present controversial issues and that allow students to be active participants in their own learning process (Kale et al., 2021). In this context, the importance of educating future physics teachers within the prevailing conditions and requirements that dictate a shift in priorities in the application of didactic tools that have not been systematically aligned to date becomes evident (Nantsou et al., 2020, 2021, 2022, 2023). The complexity of the process of transformation of predominantly practice-oriented teaching of physics students lies in the fragmentation of the results reflected in research works, which do not allow to form a scientifically sound basis for the application of the potentialities of innovative material/products necessary for implementation (Pawlak et al., 2020; Lemay et al., 2020).

The fragmentation of out-of-system ideas about innovations in the field of teaching subjects/disciplines in general and physics in particular, contributes to the chaotic nature of their practical application, which does not allow to solve the actual problems of our time and achieve the set educational goals (Psycharis et al., 2020). Thus, powerful innovative tools remain ”aside” from the realized pedagogical practices (Rapanta et al., 2020).

The differences in pedagogical didactics of the new century, manifested by trends in the development of global and national education, are observed by representatives of different scientific communities (Stern et al., 2017). The penetration of digital technologies into the ”paper” education of digital, social digital and generation Z generations has led to the emergence of a ”high-tech environment” that has changed their way of life, thinking, mode of communication and social behavior (Coccia et al., 2020). As a result of the factor influence of the named environment, the pedagogical toolkit was forced to transform, adapting to new social challenges and to the requirements of the ”science of education, teaching and learning” (Hussein and Natterdal, 2022)

The integrative nature of education, accompanied by a package of reforms including shifting educational values, standardization of curricula, variability of assessments, decentralization of management, privatization of education and liberalization of methodological support, has defined the concept of educational development in most countries (Henderson et al., 2020). The aim of the study is to summarize the changes in pedagogical didactics in order to understand the ongoing transformations and to develop a universal toolkit to manage them within physics teaching.

## METHODS

The organization of the study was presented in the form of activities carried out in stages. Each stage solved a specific task, the totality of the results of which contributed to the achievement of the main goal. When solving the tasks, the methods corresponding to them were involved. Within the framework of the first stage the sample of participants was designated, which were 24 physics teachers: from 31 to 35 years - 32%, from 36 to 43 years - 46%, from 44 to 52 years - 22%; teaching experience: from 5 to 8 years - 28%, from 9 to 11 years - 51%, from 12 to 17 years - 21%. The majority of respondents were women (82%). The second stage of the experimental activity was devoted to questionnaire design and direct interviewing of respondents, conducted in equal conditions for all and with their written consent to participate in the questionnaire. The third stage included the analysis of the recorded data and their mathematical processing with the provision of final research achievements.

Data collection was carried out in order to identify the range of conditions of teachers› noting of routine in teaching and their decision to introduce innovations in teaching physics, taking into account the results of long-term planning. The theoretical analysis of the issues covered in the scientific works of scholars in the context of the research topic allowed the development of a questionnaire and a questionnaire guide as a data collection tool. The structure and design of the questionnaire were organized according to the type of structured interview (Table 1). All participants were asked the same questions, the sequence of which was established during the interviewing process. Questions about the routine of teaching were included from positions 1 to 3, and questions about the introduction of innovations and the long-term perspective of their impact were included from positions 4 to 6 on the questionnaire. Interviews, each lasting between 30 minutes and 1 hour, were conducted using a tool provided by Zoom. Written consent for the interviews was obtained from all participants. The survey period- was from May through July 2024.

**Table 1.** Questions for the survey of physics teachers

| № | Questions |
|---|---|
| R1 | What curricula have undergone changes in the last 3 years? |
| R2 | What changes have you made that have been positive in terms of improving the quality of student learning in physics? |
| R3 | What benefits have you seen as a result of the changes you have introduced to physics teaching? |
| R4 | What changes resulted in a negative outcome? |
| R5 | How did you deal with the problem of negative results and what were your approaches to solving it? |
| R6 | Which of your approaches have been successful? |
| R7 | Which of the approaches that you find successful have you used repeatedly in teaching? |
| R8 | What long-term changes in teaching do you anticipate for the future? |
| R9 | What changes to your teaching are you continuing to implement now and why? |
| R10 | How do you assess blended (digital and traditional) learning formats? What do you see as the potential and challenges? |

Physics teachers from completely different educational institutions of the Republic of Azerbaijan were involved in the interviewing to maximize the heterogeneity of interviewers by age, gender and professional experience. A total of 24 teachers were interviewed. The weekly teaching load of the interviewees ranged from 2 to 16 hours per week for one semester. Some interviewees taught only practice-oriented classes (seminars, laboratory work) with 10 to 30 students, while others gave lectures with 50 to 130 students. Teaching experience ranged from 3 to 35 years

**Table 2.** Categories for content analysis

| Category | Description |
|---|---|
| Training procedures | Actions in the learning process that were typically performed before and during the introduction of the innovation. |
| Changes in teaching | Changes in organization, performance, understanding of the course, student interaction, and the role of the instructor. |
| Assessment of changes | Changes that the teacher believes should occur in the future as a result of the introduction of the innovation |
| Expected changes in education in the future | Teacher's anticipated changes in the future as a result of , caused by the introduction of the innovation. |
| Evaluation of the hybrid approach | Perception of the combined use of traditional and innovative teaching methods |
| Strategies employed | Long-term application of innovations in the conditions of continuity of the educational process |

and age- ranged from 30 to 65 years. The data recorded during the interview was analyzed and evaluated through qualitative content analysis based on 6 categories created deductively (Table 2). The rules of analysis and validity criteria for the data recorded in the protocols were also applied, through the procedure of measuring the level of agreement between the interviewer and the categories and checking the reliability of the analyzed data. After that, the data were analyzed and classified using QCAmap, a content analysis tool. The degree of agreement in classification was validated using the Kappa Cohen coefficient, resulting in a significant agreement with a coefficient of 0.78. The results for each category were summarized separately and then compared and interpreted. In this way, differences and similarities in the data collected through interviewing were identified

## RESULTS AND DISCUSSION

When analyzing the results of interviewing, the answers that were located on the priority positions (the first three) were mainly studied. According to the results of the interview, about 92.42% of teachers recognized the independent introduction of innovative teaching methods into the educational process in order to solve educational tasks within the framework of mastered teaching material. At the same time, when asked about the source of knowledge, all of them pointed to the autonomous mastering of new material presented in the studies of authors - representatives of scientific communities of different countries. Thus, we should ignore the opinion put forward by some researchers about the negative attitude of the majority of teachers to innovations in education. The experience of applying innovations in their pedagogical practice that teachers have and noted during the interviewing confirms our assumption.

Despite the remaining unresolved issues in the organization of didactic teaching system, almost all interviewed teachers recognize the strengths of applying innovative teaching methods, indicating their positive impact on: dynamics of students' activity in cognition and activity -51,52%; growth of interest in the implementation of practice-oriented activities within the framework of training sessions 39.93%; consciousness and stability of acquired knowledge and competences 36,36%; possibility to perform differentiated tasks, which allow to keep a high motivational interest in learning and to force in some case the time limits outlined for mastering a separate topic 33,33%; development of creativity and critical thinking -30,30%; maintaining a balance in the control and independence shown by students in the course of mastering new learning information -15.15%.

Among the reasons that cause risks in teaching using innovative methods, teachers named: reduction of knowledge in limited class time -54.55%; material support / equipment for the full organization of the learning process taking into account the latest achievements in the field of technical support of students' learning and research activities 42,42%; labor intensity of training that provides for additional involvement of the teacher in virtual interaction with students in order to ensure the quality of the processes implemented by him/her -36.36%.

According to the teachers, the application of innovation in the learning process has always been driven by necessity for various reasons, including: deficit of students' interest in mastering subject knowledge in physics- 92,42%; low degree of students' involvement in practice-oriented activities an -important component of teaching and learning physics 69.7%; insufficient development of students' creative abilities- 60,61%. When asked to determine the ratio of adoption of traditional (reproductive) and innovative teaching methods, teachers responded as follows (Figure 1). When determining whether teachers have a built in strategy for introducing innovations into the process of teaching physics to students, results were obtained indicating its absence in most cases (Figure 2).

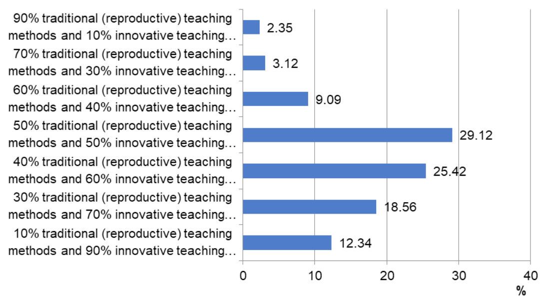


**Figure 1.** Relationship between the application of traditional and innovative teaching methods

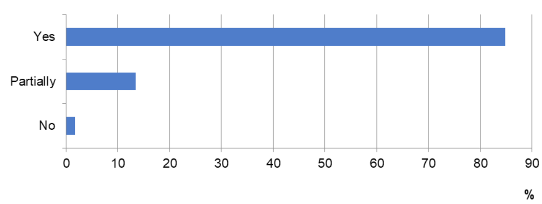


**Figure 2.** Existence of a strategy for introducing innovative methods of teaching physics

In our opinion, it is the innovative culture with the motive and ability to update pedagogical tools, competencies, knowledge and values that should become a component of the mastery of a modern physics teacher. Such a system can be multicomponent and multilevel, connected with reflexive methodological competence of teachers.

This section presents the results of the study, sorted in such a way as to answer the research questions in order to achieve its purpose. First, we summarize some of the teaching procedures used by the teachers in the classroom, retained because of their effectiveness from the interviewees' point of view. Then, we dwell on the presentation of didactic innovations introduced by the teachers in the process of teaching physics to the students of the educational institution. Also, we briefly disclose the results of the question, formulated in such a way as to get an answer to the number of teachers who would like to keep or continue the development of didactic innovations proposed and implemented by them in the process of teaching physics to students in their future professional activity, giving them a systematized form of pedagogical strategy.

In accordance with the results of the study, there were obtained data indicating the predominantly analog or synchronous learning, prevailing within the traditionally organized educational process and not allowing to improve the quality of teaching physics to students. With the preservation of the content of academic disciplines in the conditions of constant changes in a wide interdisciplinary range of scientific achievements, in the opinion of teachers-interviewers, it is impossible to model the organization of the learning process with the use of new didactic tools of learning interactions.

In addition, the interviewees pointed out the decrease in students' activity in case of preserving teaching traditions due to the time and space limitations of the interaction environment, as well as the inexpediency of using synchronous learning techniques to involve them in the full exchange of academic knowledge and control over the degree of their mastery. In order to counteract this problem, teachers used group work with the introduction of new digital programs, to overcome the distance through collaborative forms of work- open educational resources, project activities with joint programming of actions and feedback. Active use of videoconferencing and chat functions allowed teachers to expand the range of digital tools to get correct and timely feedback from students, thus optimizing the didactic development of academic disciplines.

Teachers noted the reduction of student's educational load as a result of the introduction of short synchronous digital classes in the learning process, thanks to which it was possible to introduce variability in the formation of the academic schedule and reduce the likelihood of developing fatigue when students master the content of the course. The use of tools offered by the Zoom program made it possible to reduce the time for identifying academic problems in students' mastering of the educational material and to jointly search for the optimal solution - "live". In this case, the complexity of establishing interactions between the subjects was practically leveled out, and the repetition and automation of decisions necessary for learning, the importance of which we discussed earlier, were ensured. Digitalization of teaching material and, accordingly, of tasks/exercises is positively evaluated by the interviewer-teachers, as it contributes to individual success in students' learning due to the increase in the level of their involvement in educational activities.

In some cases, students' self-study materials used automatic feedback- closed quizzes or assignments, and in some cases, after studying the materials, students were asked to write short tests indicating their informed understanding of the learning material they had studied. The use of a wide range of Internet sources, which differed greatly in the quality of information provided, led to the need to teach students information skills to evaluate various media for usefulness and credibility. In fact, teachers were forced to activate and introduce new tools capable of ensuring the formation of professional competence of future physics teachers, which is significant in the current realities of the organization of educational practices.

The teachers' concerns were raised by the remaining unresolved issue of further integration of author's approaches to the development of teaching material into synchronous (traditional) forms of teaching. Many interviewees questioned the current methods of integration due to the time required to create high quality digital materials for teaching, for example, the practical component of curricula. This problem was partially solved by videos created by some teachers to explain the practical blocks of the curriculum, but this did not solve the problem of organizing students' experimental activities.

The solution to this problem lies more in the space of financial possibilities of the educational institution, as the implementation of modeling processes requires expensive equipment. Although the interviewees described many creative ways in which they attempted to preserve the practical nature of physics teaching, they still evaluated the solutions found rather negatively. In the process of finding effective solutions in an attempt to follow scientific advances "without being late", the teachers noted a positive expansion of the range of their professional competencies, manifested in visualizing work results, providing feedback, or structuring group processes.

Most interviewees recognized a desire to maintain the experience gained in the long-term perspective of teaching physics, as well as to increase the didactic tools they already have by using Moodle, Chamilo or cloud platforms as a repository for, for example, homework assignments intended for students. Teachers in the interviews expressed a desire to maintain flexibility within the organizational forms of synchronous and asynchronous learning, in the future and to integrate it into classroom teaching. In the future, faculty would like to find new ways to ecologically combine the benefits of traditional and innovative learning to create part of the educational process as an augmented environment to improve the quality of out-of-classroom interaction and student engagement in learning new information.

The set of desires expressed in the course of interviews by teachers indicates the need to develop theoretical and methodological foundations for creating an asynchronous concept of teaching physics to students, allowing them to form skills of professional self-organization. The teachers see the long-term application of the skills already acquired in the educational practice of organizing asynchronous digital learning in the use of high-quality training modules and open educational resources that promote academic success of students, but with the preservation of practical components of physics teacher education programs.

The implemented research was aimed at establishing didactic innovations applied by physics teachers in educational institutions of the Republic of Azerbaijan. The implemented research has limitations that do not allow obtaining reliable values in quantitative indicators and results of innovations implementation in teaching physics, but reveals the general trend of practices of innovations implementation in the educational process of institutions of the Republic.

The results of the study revealed a stable relationship between routine and innovation, the aggravation of which is manifested by the dynamics of teachers' reflections on the need to make changes in teaching physics. Interviewers point out the possibility of continuing to use in pedagogical practice some didactic procedures, the implementation of which demonstrates sustainable positive results. In particular, joint planning and preliminary discussion of the content of the course being mastered with students, introduction of certain didactic methods or formulation of tasks and exercises.

Several factors acted as a starting point that triggered the introduction of innovations, among which we highlighted: the inconvenience of using paper media as sources of educational information due to the lag in its provision compared to advances in science; spontaneous control of interaction processes during the organization of the educational process in general and during classes in particular; low level of training of students included in practice-oriented activities within the framework of laboratories provided by the educational institution.

We find confirmation of our results in the studies of other authors Guerrero et al. (2020), Hussein and Natterdal (2022), Kong et al., (2020), Miralles-Martínez et al. (2019), Paricio Royo et al. (2020), Pirker et al. (2020), Sosa Díaz et al. (2021), which, in our opinion, shows the interdisciplinarity and cross-nationality of their nature. Research in physics education is often considered a pioneer in the field of education, despite the fact that it relies on knowledge gained by analyzing results from other, more studied disciplines. By integrating results, we envision the possibility of future research, the focus of which is determined by current educational and research goals.

Cognitive and educational research involving the study of physics has gathered a rich literature on student learning behavior, as well as a number of frameworks. Some of the popular frameworks include conceptual understanding and conceptual change, problem solving, knowledge structure, deep learning, and knowledge integration. In line with twenty-first century skills, future research in physics learning should aim to integrate multiple areas of existing work so that it helps students develop well-integrated knowledge frameworks to achieve deep learning in physics

The extensive literature on physics learning and scientific reasoning can provide a solid foundation for further development of effective approaches to physics instruction, such as, active interaction instruction and research labs specifically targeting scientific inquiry abilities and reasoning skills. Because scientific reasoning is a more general cognitive ability, success in physics may also more readily influence research and educational practices in other knowledge domains as well. Developing and maintaining a supportive infrastructure for educational research and its implementation has always been a challenge, not only in physics. Twenty-first century education requires researchers and educators around the world to work together as an extended community to create a sustainable integrated educational environment. With this new infrastructure, effective team teaching and meaningful assessment can be provided to help students develop a complex set of skills, including deep understanding and scientific thinking, as well as communication and other non-cognitive abilities.

The proposed research will provide insights and resources to support instructional practices aligned with the Next Generation Science Standards that explicitly emphasize three domains of learning, including disciplinary core ideas, cross-cutting concepts, and practices. The first goal of promoting deep learning of disciplinary knowledge aligns well with the emphasis on disciplinary core ideas that are central to helping students develop well-integrated knowledge structures to achieve deep understanding. The second goal for developing transferable scientific reasoning skills supports the emphasis on cross-cutting concepts and practices. Scientific reasoning skills are complex cognitive abilities that are necessary to develop general subject matter concepts and modeling strategies. In addition, the development of scientific reasoning requires research-based instruction and practice. Thus, research on scientific reasoning can provide a valuable knowledge base of instructional tools effective for developing crosscutting concepts and promoting meaningful practices in STEM. The third research goal addresses the challenge of assessing high-level skills and disseminating effective educational approaches, which supports all sustainability and long-term impact initiatives.

The results of our study also indicate a great variability of digital tools implemented by teachers independently to achieve high efficiency of interactions during the broadcasting of educational information. For example, teachers use new forms of class organization, combining methods of synchronous and asynchronous learning, their own learning tools to increase student motivation and self-organization in the form of open educational resources with many creative tasks, different from traditionally used educational practices. The format of lectures, the information material of which is now converted by the majority of teachers into digital material, allowing the realization of asynchronous learning, has undergone changes. In addition to lectures, electronic tutorials, seminars and exercises modeled by the instructor with the participation of the students themselves are offered.

## CONCLUSION

The results of interviewing allowed us to understand: firstly, how dynamic is the process of improving teachers' pedagogical skills and mastering innovations in teaching and learning. Secondly, how "independent" is the process of updating teachers' pedagogical skills. Thirdly, what is the complexity of modernization of the educational process designed to carry out professional training of future physics teachers in the current conditions. The main result of the study, designed to answer the question: "To what extent should the didactic toolkit for teaching and training students in physics be preserved or changed?", was obtained according to the totality of all answers, and indicated the need to develop high-quality didactic material, preferably in the form of open educational resources. In addition, the results of the study allow us to conclude about the mandatory development of tools for controlling the quality of learning information assimilation and individual level of students' preparedness to carry out their professional activity upon graduation from educational institution.

According to the results of the study, special attention should be paid to preserving or even increasing the degree of variability of forms of full-time training by developing a mechanism for integrating synchronous and asynchronous training of future physics teachers, which entails changing the time parameters in the standardized schedule of the educational institution.Whether didactic innovations will be introduced in the long term and improve the teaching of physics to students depends not only on teachers' wishes, ideas and positive evaluations, but also on institutional and policy decisions at the meso- and macro-levels. Interviewees regularly mentioned these levels when emphasizing the need for technical equipment and software for digital and professional support in the creation of teaching materials or institutional guidelines. Based on the presented results, a new study can be designed to explore the actual effects and interactions of levels of innovation in the future.

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